ECONOMICS & Sociology

Vasa, L. & Kenzhegulova, G. (2026). Structural assessment of Kazakhstan's financial system using taxonomic and grey system methods. *Economics and Sociology*, *19*(2), 155-172. doi:10.14254/2071-789X.2026/19-2/7

STRUCTURAL ASSESSMENT OF KAZAKHSTAN'S FINANCIAL SYSTEM USING TAXONOMIC AND GREY SYSTEM METHODS

László Vasa
Vytautas Magnus University, Kaunas, Lithuania
Email: vasalaszlo@gmail.com
ORCID 0000-0002-3805-0244

Gaukhar Kenzhegulova
Széchenyi István University, Győr, Hungary
Email: gaukhar.kenzhegulova@gmail.com
ORCID 0000-0002-1232-4788

Received: June, 2025
1st Revision: April, 2026
Accepted: May, 2026

DOI: 10.14254/2071-789X.2026/19-2/7

ABSTRACT. The expansion of digital payments, online banking, and cashless transactions has transformed the structure of financial systems and the circulation of money. This study analysed the impact of digital financial activity on the structural relationships between banking infrastructure and monetary indicators in Kazakhstan. Annual data for 2016–2025 were grouped into four analytical blocks: Digital Transaction Activity; Banking Infrastructure and Online Access; Monetary and Banking Structure; and Financial Sector and Monetary Circulation. The methodology included Z-score standardisation, Hellwig taxonomic analysis, Grey Relational Analysis, and PCA biplot analysis. Digital financial indicators changed unevenly and did not form a unified trend at the beginning of the period. After 2020, the use of online banking, internet transactions, payment cards, and cashless payments increased. Digital financial activity demonstrated a nearly equal degree of structural interconnection with all three blocks of the financial system. Digital, banking, and monetary indicators formed interrelated groups. Overall, the results showed that digital financial activity ceased to be an independent element characterising only payment transactions. By the end of the study period, it had become a structural component of the financial system, closely linked to banking infrastructure and monetary circulation.

JEL Classification: C38, E42, G21, G23, O33

Keywords: digital finance, fintech, digital payments; banking infrastructure; online banking; financial circulation; cashless transactions; digital financial activity

Introduction

The introduction should briefly place the study in a broad context and highlight why it is Digital technologies are transforming the financial system as digital payments, mobile banking, and remote financial services continue to expand. However, the impact of this process on the financial system as a whole remains understudied. However, it remains unclear whether digital financial services influence only payment activities or also affect banking infrastructure, money circulation, deposits, liquidity, and other monetary indicators. This suggests that digital

financial activity should be examined as a factor shaping relationships among the various components of the financial system.

The development of digital financial services has been uneven across countries and has depended on factors such as banking infrastructure and digital accessibility. Different models of digital financial inclusion have emerged in Southeast Asian countries (Koh et al., 2018). In Singapore and Malaysia, digital financial services have been developed through banking infrastructure, digital banking systems, and online transactions. In contrast, in Cambodia, their expansion was based on mobile transfers and remote financial operations. In all countries, contactless and remote financial transactions have become increasingly important. Differences in technological readiness and the level of digital financial infrastructure determined which financial instruments were used and which digital formats replaced traditional operations.

For ASEAN countries, the impact depended on the country's level of infrastructural and institutional readiness (Quoc et al., 2025). In Indonesia, Malaysia, and Thailand, digital financial inclusion expanded access to financial services and supported the development of the digital economy. In Vietnam, digital financial inclusion remained limited because of low digital adoption and unequal access to digital financial services. Similar patterns were observed in Europe. In Hungary and Poland, the wider use of mobile banking and online financial platforms contributed to the wider adoption of FinTech applications (Kurucz et al., 2025).

For Kazakhstan, the expansion of digital financial services has become particularly important amid the rapid growth of cashless payments, online banking, mobile financial applications, and remote financial services over the last decade. The growing role of digital transactions and online financial services is expected to influence the structure of financial circulation and the interaction between banking infrastructure and monetary indicators. At the same time, the structural effects of digital financial activity on banking infrastructure and monetary components remain insufficiently studied in Kazakhstan's financial system.

The purpose of this study was to analyse the impact of digital financial activity on the structural relationships between banking infrastructure and monetary indicators in Kazakhstan.

1. Literature review

1.1. Evolution of digital financial systems and payment infrastructure

Electronic payments gradually began to occupy a central place in the financial system (Humphrey et al., 1996). Electronic payment instruments developed within a common digital infrastructure could complement each other through POS systems, electronic transfers, and remote banking services. Electronic payments began to displace paper-based payments (Khiaonarong, 2001). The use of cash declined slowly, but the development of electronic networks, automation of settlements, and the reduction of transaction costs accelerated the spread of digital financial transactions (Andrieu, 2001). Banks began to create more favourable conditions for consumers, favouring electronic transactions (Humphrey et al., 2001). Paper payments were more expensive for consumers than electronic transactions. At the same time, the number of POS terminals was rapidly growing. As a result, consumer payment behaviour began to change, displacing paper payments and reducing cash payments.

Nevertheless, implementing any digital tool or mechanism requires adapting the payment system infrastructure and increasing user trust. The introduction of online banking and electronic transactions enabled customers to interact remotely (Berger, 2003; Putrevu & Mertzanis, 2024; Roshchyk et al., 2022). The development of the banking system has accelerated financial transactions and expanded lending (Liu & Hsu, 2006). However, digital payments do not always lead to higher economic growth (Pang et al., 2022). At the same time,

economic growth has accelerated the development of banking services and financial infrastructure (Nabi & Suliman, 2009; Shaikh et al., 2017; Makarenko et al., 2025). In particular, for developing countries with a higher share of the shadow economy, the development of digital payment infrastructure and the modernisation of banking systems increase the transparency of financial flows. As a result, tax control is strengthened, the role of electronic retail payments in GDP and trade increases, and some financial transactions are shifting to the formal sector of the economy (Zhang et al., 2019).

Different components of digital transformation, including the modernisation of banking infrastructure and the development of digital payment instruments, have different economic effects (Yarovenko et al., 2025). For OECD countries, the speed of financial transactions, reduced transaction costs, and ease of use of payment systems are particularly important (Wong et al., 2020). Therefore, the roles of debit and credit cards differ. Debit card payments promote cashless transactions and speed up payments. At the same time, they add virtually no debt to households. Credit card use increases household debt and credit risk. Evidence from the Czech Republic shows that EFTPOS card payments positively affect economic growth (Srivastava & Řežábek, 2022). Expanding cashless payments, encouraging online banking, and optimising banking infrastructure contribute to greater financial transparency and strengthen financial stability (Bozhenko et al., 2024).

1.2. Digital finance, FinTech and transformation of banking systems

The structure of the credit market and financial assets has begun to change under the influence of the digitalisation of financial services, the expansion of e-lending, and the emergence of new forms of financial intermediation. The expansion of digital financial instruments, e-lending, and FinTech platforms has accompanied economic development. In countries with more developed digital infrastructure, online payments, digital services, and electronic financial transactions have grown faster (Dos Santos & Harvold Kvangraven, 2017). At the same time, the forms of interaction between consumers, businesses, and financial institutions have changed (Frost et al., 2019; Cornelli et al., 2023; Kráľ et al., 2025). However, even with a well-developed digital payment infrastructure, consumers' and businesses' trust and willingness to use digital tools remain key. In India, despite the availability of digital infrastructure, the adoption of digital payments remained limited because users were concerned about greater tax oversight (Ligon et al., 2019). Moreover, Belke and Beretta (2020), using European countries as an example, showed that traditional payment systems continue to play an important role, while digital instruments are developing in parallel with traditional banking mechanisms. Kasri et al. (2022), using Indonesia as an example, found a long-term cointegrating relationship between the spread of digital payments and banking system resilience. The growth of digital payments was accompanied by greater resilience in the banking system, driven by higher non-cash transactions, fee income, and accelerated cash turnover.

The growth of digital financial transactions has led to increases in transferable deposits, NBK deposits, and other deposit components, while cash in circulation has gradually declined. At the same time, the structure of bank assets and reserves has changed, including domestic and foreign assets, as well as net foreign assets. The development of digital financial instruments has accelerated the redistribution of financial flows within the banking system and increased the interconnection between the credit, deposit, and settlement components of financial circulation (Carbó-Valverde, 2017).

1.3. Digital finance during and after COVID-19

The development of FinTech and digital banking expanded remote financial services, including electronic lending (Puschmann, 2017; Gomber et al., 2018; Guo & Liu, 2022). This also increased the interaction among deposits, loans, equity, government-sector claims, and other components of the financial system. Paduszyńska and Lesiak (2022) showed that the stability of banking systems depended more strongly on capital structure, liquid assets, and deposit coverage. The growth of non-cash transactions, commission income and acceleration of funds turnover contributed to the development of digital lending and FinTech platforms, increased the resilience of the banking system, and also influenced the sustainability of commercial banks and capital structure (Kasri et al., 2022; Cornelli et al., 2023; Liang et al., 2025; Alfons & Pandin, 2025). Despite the acceleration of digital lending and the development of FinTech platforms, the further development of digital financial infrastructure requires adapting banking systems, users, and financial interaction mechanisms. Thus, the next stage of financial sector transformation was based on changes in consumer behaviour and practices, the adoption of new digital solutions within existing banking infrastructure, and investments in compliant digital systems (Hughes et al., 2024).

The development of FinTech and digital payments accelerated during the COVID-19 pandemic, decreasing reliance on traditional banking services. Restrictions introduced during the pandemic affected user behaviour, leading to increased use of mobile payment services and growth in remote financial transactions (Daragmeh et al., 2021). The development of digital finance, mobile banking, and electronic financial services has increased financial inclusion and increased banks' reliance on technological infrastructure and digital customer interaction channels (Banna & Alam, 2021). At the same time, the development of digital financial services has strengthened the relationship between bank liquidity, lending, and money supply (Jiang et al., 2022). Cashless and contactless payment methods ensured consumer safety and thus gained more interest (Alchuban et al., 2022). With the introduction of mobile banking, the number of microloans, instalment plans, and online transactions increased. Consequently, mobile banking has become a priority tool for building credit history (Tut, 2023; Dluhopolskyi et al., 2023). Furthermore, the digital financial system has expanded access to finance for small businesses and vulnerable and low-income populations (Khan et al., 2025; Shahen & Sharaf, 2026). At the same time, faster movement of funds within the financial system changed the velocity of money circulation and the structure of financial flows (Gurgur & Kahveci, 2025).

1.4. Research gaps in digital financial transformation

Digital transformation should be viewed as a multidimensional process. Pakhnenko et al. (2021) developed an integrated Digital Financial Services Index based on digital inclusion, financial inclusion, and digital financial services, highlighting the multidimensional nature of financial digitalisation. Therefore, digital transformation should be viewed as a multidimensional process. Limited attention has been paid to the interrelationships among digital financial transactions, liquidity structures, deposits, reserves, credit distribution, and monetary circulation in emerging economies. In addition, the effects of digital financial transformation on the broader structure of financial assets, liabilities, and banking indicators remain insufficiently explored in Kazakhstan. Therefore, this study examines the relationship between digital financial development and changes in the structure of financial circulation, banking liquidity, deposits, reserves, and credit components.

2. Methodology

The research was based on official statistics published by the National Bank of Kazakhstan (2025) and the Agency of the Republic of Kazakhstan for Regulation and Development of the Financial Market (2025) and covered the period from 2016 to 2025. The dataset includes indicators of payment transactions, banking infrastructure, online banking, monetary aggregates, deposits, claims, loans, and financial sector statistics. The first block included indicators of payment and transaction activity through POS terminals, ATMs, and internet banking channels. The second block covered the development of card and online banking infrastructure, including payment cards, ATM networks, and active users of digital banking services. The third block reflected the monetary and banking structure through assets, reserves, deposits, liquidity, and credit indicators. The fourth block incorporated indicators of the financial sector and monetary circulation, including financial assets, deposits, loans, equity, and cash outside the financial sector.

Table 1. Structure of financial and banking indicators used in the analysis, 2016–2025

Sub-block	Indicators	Unit	Codes
Block 1. Digital Transaction Activity			
POS transactions	Cashless transactions (volume, value); cash withdrawal transactions (volume, value)	thousand transactions; mln KZT	POS_TRN, POS_VOL, POS_CASH_TRN, POS_CASH_VOL
ATM transactions	Cashless ATM transactions (volume, value); cash withdrawal ATM transactions (volume, value)	thousand transactions; mln KZT	ATM_TRN, ATM_VOL, ATM_CASH_TRN, ATM_CASH_VOL
Internet transactions	Internet cashless transactions (volume, value)	thousand transactions; mln KZT	WEB_TRN, WEB_VOL
Block 2. Banking Infrastructure and Online Access			
Payment cards	Cards in circulation; active cards	thousand units	CARD_TOTAL, CARD_USED
ATM infrastructure	Number of ATMs; cash-out ATMs; cash-in/out ATMs	units	ATM_NUM, ATM_OUT, ATM_INOUT
Online banking	Active online banking users	thousand units	ONLINE_USERS
Block 3. Monetary and Banking Structure			
Assets and reserves	Net foreign assets; domestic assets; reserves	mln KZT	NFA, DA, RES
Deposits and liquidity	NBK deposits; transferable deposits; other deposits; cash in circulation	mln KZT	NBK_DEP, TRANS_DEP, OTH_DEP, CASH
Credit structure	Government claims; NFC claims; household claims; loans	mln KZT	GOV_CLAIM, NFC_CLAIM, HH_CLAIM, LOANS
Block 4. Financial Sector and Monetary Circulation			
Financial assets	Foreign assets; domestic claims	mln KZT	F_NFA, F_CLAIM
Financial liabilities and circulation	Deposits; cash outside the financial sector	mln KZT	DEP, OUT_CASH
Credit and capital structure	Government sector claims; other sector claims; loans; equity	mln KZT	F_GOV, F_SECTOR, CREDIT, EQUITY

Source: Compiled by the authors based on data from the National Bank of Kazakhstan (2025) and the Agency of the Republic of Kazakhstan for Regulation and Development of the Financial Market (2025)

At the first stage, all indicators were standardised using z-score normalisation to eliminate differences in measurement units and ensure comparability across variables, according to the following formula (1):

$$Z_{ij} = \frac{X_{ij} - \bar{X}_j}{S_j} \quad (1)$$

where:
Z_{ij} – standardised value of indicator j in year i;
X_{ij} – actual value of indicator j in year i;
$\bar{X}_j$ – mean value of indicator j;
S_j – standard deviation of indicator j.

The standardised indicators were grouped into four structural dimensions: Digital Transaction Activity, Banking Infrastructure and Online Access, Monetary and Banking Structure, and Financial Sector and Monetary Circulation.

At the second stage, the Hellwig taxonomic method was used to evaluate the relative development level of each structural dimension. For each indicator, the maximum standardised value was selected as the reference pattern. The Euclidean distance between each year and the reference vector was calculated by formula (2):

$$D_i = \sqrt{\sum_{j=1}^{m} (Z_{ij} - Z_j^0)^2} \quad (2)$$

where:
D_i – Hellwig distance for year i;
Z_{ij} – standardised value of indicator j in year i;
Z_j^0 – reference (maximum) value of indicator j;
m– number of indicators included in the structural block.
The critical distance was determined using the classical Hellwig procedure (3):

$$D_0 = \bar{D} + 2S_D \quad (3)$$

where:
$\bar{D}$ – mean value of Hellwig distances;
S_D– standard deviation of Hellwig distances.
The taxonomic development index was then calculated as (4):

$$HDI_i = 1 - \frac{D_i}{D_0} \quad (4)$$

where:
HDI_i – taxonomic development index for year i;
D_i – Hellwig distance for year i;
D_0 – critical distance.

At the final stage, Grey Relational Analysis was applied to examine the structural relationship between digital transaction activity and the remaining financial dimensions. Digital

Transaction Activity was selected as the reference sequence. Absolute differences between the reference and comparative sequences were calculated by formula (5):

$$\Delta_i(k) = |X_0(k) - X_i(k)| \quad (5)$$

where:
$\Delta_i(k)$– absolute difference for year k;
$X_0(k)$– reference sequence value;
$X_i(k)$ – comparative sequence value.
The Grey Relational Coefficient was estimated as (6):

$$\gamma_i(k) = \frac{\Delta_{min} + p\Delta_{max}}{\Delta_i(k) + p\Delta_{max}} \quad (6)$$

where:
$\gamma_i(k)$ – Grey Relational Coefficient;
Δ_{min} – minimum difference observed in the matrix;
Δ_{max} – maximum difference observed in the matrix;
p – distinguishing coefficient, set at 0.5.

The final Grey Relational Grade was obtained as the arithmetic mean of the coefficients for each structural dimension (7):

$$GRG_i = \frac{1}{n}\sum_{k=1}^{n} \gamma_i(k) \quad (7)$$

where:
GRG_i – Grey Relational Grade for structural dimension i;
n– number of observed periods.

The combined approach of taxonomic analysis and Grey system methods enabled assessment of both the development of structural financial dimensions and the intensity of interrelationships between digital transaction activity and broader monetary-financial processes in Kazakhstan.

After calculating integrated taxonomic indices and Grey Relational indicators, a Principal Component Analysis (PCA) biplot was applied to the initial standardised variables. The PCA biplot was used to identify the internal structure of relationships between individual financial indicators and to determine which variables contributed most strongly to the observed structural transformations.

3. Empirical results

The results section presents two analytical parts. The first part presents the results of Hellwig's taxonomic analysis, which assesses changes in Kazakhstan's structural financial dimensions from 2016 to 2025. The second part includes the results of Grey Relational Analysis, applied to determine the degree of interconnection between digital transaction activity and other components of the financial system.

First, the results of Hellwig's taxonomic analysis are considered. The calculated indices show changes in the level of development of digital transaction activity, banking infrastructure, monetary structure, and financial circulation during the period under review.

Table 2 presents the Hellwig method results, reflecting the distance between the actual state of structural financial indicators and the benchmark state for 2016–2025.

Table 2. Hellwig distances across structural financial dimensions in Kazakhstan, 2016–2025

Structural Dimension	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Digital Transaction Activity	6,57	6,01	5,23	8,36	8,58	8,10	7,66	6,41	6,04	5,69
Banking Infrastructure and Online Access	6,07	5,80	5,45	4,80	4,83	3,77	2,56	2,32	2,38	3,15
Monetary and Banking Structure	9,02	8,84	8,46	8,32	7,28	5,55	5,14	4,34	3,48	2,91
Financial Sector and Monetary Circulation	8,58	8,42	8,10	7,81	6,50	5,90	5,12	4,20	2,04	0,00

Source: own evaluation

The most pronounced reduction in the distance was observed in the Monetary and Banking Structure, the Financial Sector, and the Monetary Circulation. The Monetary and Banking Structure value decreased from 9.02 in 2016 to 2.91 in 2025, while the Financial Sector and Monetary Circulation decreased from 8.58 to 0.00. The gap between the actual state of the financial and banking system and the reference level was narrowing, leading to an increase in the deposit base, domestic claims, and money circulation, and to a strengthening of financial sector indicators. The most significant change in financial services and transaction acceleration occurred after 2020.

Banking Infrastructure and Online Access also showed a steady decline in distance, from 6.07 to 3.15, with the minimum values in 2022–2024. Therefore, during this period, there was a significant increase in the number of cards used, online banking users, and cash-in-hand ATMs.

Digital Transaction Activity showed greater variability over the study period. After a decrease from 6.57 in 2016 to 5.23 in 2018, the distance increased to 8.58 in 2019–2021. In subsequent years, the distance decreased again to 5.69. These changes indicate that transaction activity developed unevenly over time. The changes were related to the rapid growth of non-cash transactions, the redistribution of transaction flows among POS, ATM, and internet channels, and changes in the structure of cash transactions in Kazakhstan's banking system.

Table 3 presents the results of the Taxonomic Index calculated using the Hellwig method for Kazakhstan's key structural financial indicators for 2016–2025.

Table 3. Taxonomic index of structural financial dimensions in Kazakhstan, 2016–2025

Structural Dimension	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Digital Transaction Activity	0,72	0,66	0,57	0,91	0,94	0,88	0,84	0,70	0,66	0,62
Banking Infrastructure and Online Access	0,12	0,16	0,21	0,30	0,30	0,45	0,63	0,66	0,65	0,54
Monetary and Banking Structure	0,84	0,82	0,79	0,77	0,68	0,52	0,48	0,40	0,32	0,27
Financial Sector and Monetary Circulation	0,77	0,76	0,73	0,70	0,58	0,53	0,46	0,38	0,18	0,00

Source: own evaluation

The Digital Transaction Activity indicator recorded the highest Taxonomic Index values. Following a temporary decline to 0.57 during 2016–2018, the index recovered to 0.91–0.94 in 2019–2020 and remained at a relatively high level thereafter.

Banking Infrastructure and Online Access increased over the observed period to 0.54 in 2025. The highest values were observed in 2022–2024, when the index ranged from 0.63 to 0.66.

The Monetary and Banking Structure, Financial Sector, and Monetary Circulation indices showed a general decline over the period under review. After 2020, the indicators for the money supply structure, bank claims, deposit components, and financial flows declined, while the share of digital transaction instruments and online transactions increased. As a result, by 2025, the Monetary and Banking Structure index fell from 0.84 to 0.27, and the Financial Sector and Monetary Circulation index fell from 0.77 to 0.00.

Table 4 presents the results of the Grey Relational Analysis for Digital Transaction Activity and the remaining structural dimensions of Kazakhstan's financial system.

Table 4. Grey relational differences across structural dimensions, 2016–2025

Structural Dimension	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Banking Infrastructure and Online Access	0,60	0,50	0,36	0,61	0,64	0,43	0,21	0,04	0,01	0,08
Monetary and Banking Structure	0,12	0,17	0,22	0,14	0,26	0,37	0,36	0,30	0,34	0,35
Financial Sector and Monetary Circulation	0,05	0,10	0,16	0,21	0,35	0,36	0,38	0,32	0,48	0,62

Source: own evaluation

* - Digital Transaction Activity was used as the reference sequence in the Grey Relational Analysis

The results showed that Monetary and Banking Structure had the smallest difference from Digital Transaction Activity throughout the period. The values ranged between 0.12 and 0.37. The lowest values were observed during 2016–2019.

The Financial Sector and Monetary Circulation also showed relatively small differences from Digital Transaction Activity in the first half of the period under review. From 2016 to 2018, values ranged from 0.05 to 0.16, but after 2020, the differences gradually increased, reaching 0.62 by 2025. This trend shows a gradual widening of the gap between digital transaction activity and the structure of financial circulation.

The largest differences were observed between Digital Transaction Activity and Banking Infrastructure and Online Access in 2016–2021, with values ranging from 0.60 to 0.64. During the COVID-19 pandemic, the indicator almost doubled — from 0.30 in 2019 to 0.64 in 2020. During this period, the use of online banking and digital payment services accelerated. After 2021, the differences sharply decreased. The lowest values for all structural blocks were observed in 2023. In 2023–2024, the Banking Infrastructure and Online Access values were 0.04–0.01, indicating almost synchronous behaviour between digital transaction activity and the development of banking infrastructure and online access. After 2023, Monetary and Banking Structure and Financial Sector and Monetary Circulation began to increase again, while Banking Infrastructure and Online Access continued to decline, reaching a minimum of 0.01 in 2024.

Table 5 presents the results of the Grey Relational Coefficients between Digital Transaction Activity and other structural financial dimensions of Kazakhstan in 2016–2025. Higher coefficient values correspond to a closer relationship between the structural blocks.

Table 5. Grey relational coefficients between digital transaction activity and structural financial dimensions in Kazakhstan, 2016–2025

Structural Dimension	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Banking Infrastructure and Online Access	0,35	0,40	0,48	0,35	0,34	0,43	0,62	0,91	1,00	0,82
Monetary and Banking Structure	0,74	0,67	0,61	0,71	0,56	0,47	0,48	0,53	0,50	0,49
Financial Sector and Monetary Circulation	0,88	0,78	0,69	0,61	0,48	0,48	0,47	0,51	0,41	0,35

Source: own evaluation

The results of the coefficient analysis revealed a strengthening relationship among Digital Transaction Activity, Banking Infrastructure, and Online Access. Until 2021, the coefficient fluctuated between 0.34 and 0.48, indicating a moderate relationship in the first half of the period under review. The remaining indicators showed decreasing coefficients, and by 2021, the values of all three indicators were nearly equal, ranging from 0.43 to 0.48.

The Banking Infrastructure and Online Access coefficient reached a maximum of 1.00 in 2024. Although the indicator declined to 0.82 in 2025, the correlation with digital transaction activity remained strong. The relationship between Digital Transaction Activity and the indicators Monetary and Banking Structure, the Financial Sector, and Monetary Circulation was weakening. Their coefficients decreased dramatically over the period and reached values of 0.49 and 0.35, respectively, in 2025.

Table 6 presents the Grey Relational Grades for Digital Transaction Activity and the main structural financial dimensions of Kazakhstan for 2016–2025.

Table 6. Grey relational grades between digital transaction activity and structural financial dimensions in Kazakhstan, 2016–2025

Structural Dimension	Grey Relational Grade
Banking Infrastructure and Online Access	0,57
Monetary and Banking Structure	0,58
Financial Sector and Monetary Circulation	0,57

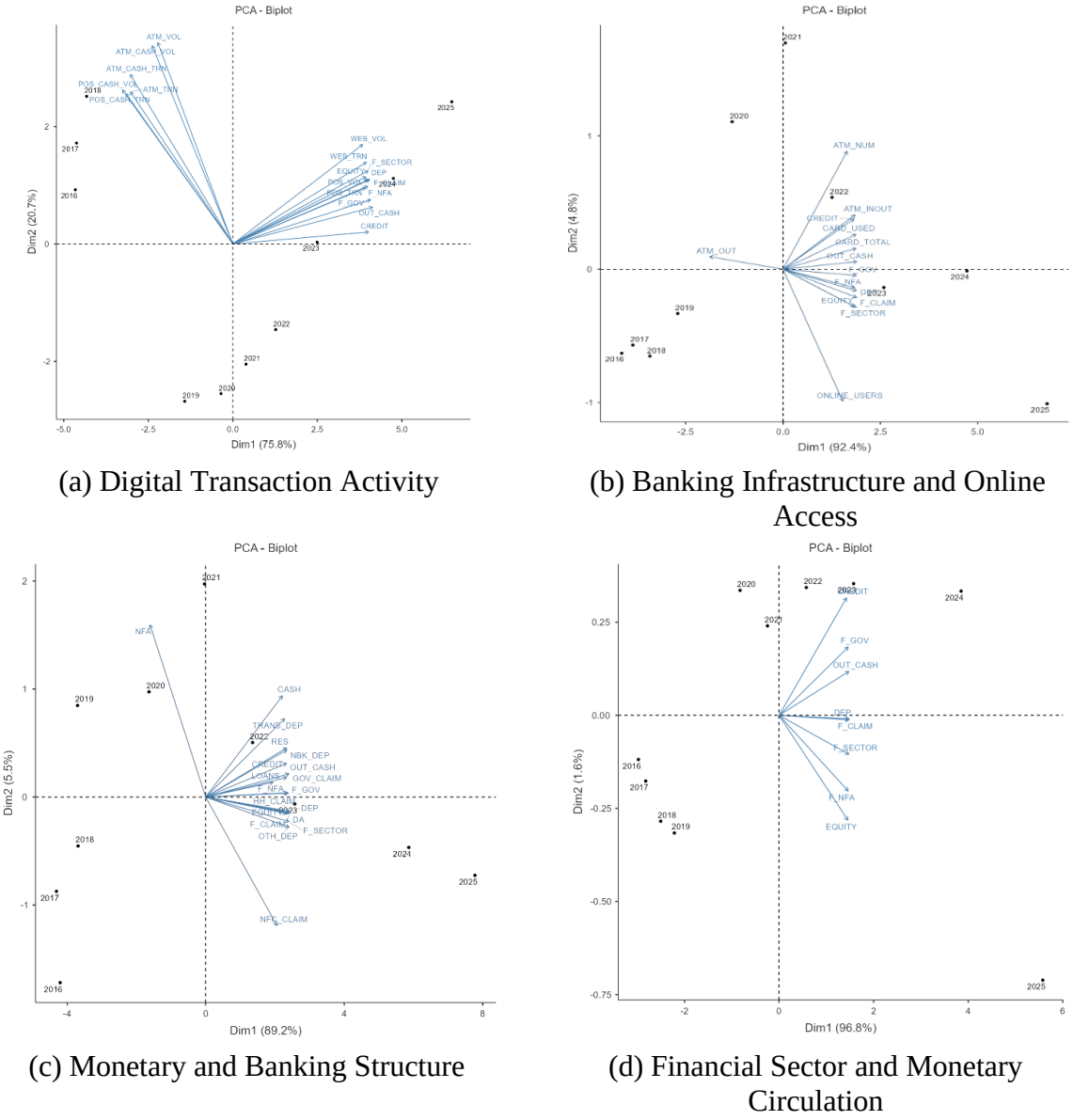
Source: own evaluation

The Grey Relational Grade showed that the Monetary and Banking Structure block had the strongest relationship with digital transaction activity. The Banking Infrastructure and Online Access, Financial Sector, and Monetary Circulation blocks demonstrated a less consistent relationship.

Nevertheless, it is necessary to determine which specific standardised indicators explained the observed structural changes and relationships. After calculating the integrated taxonomic and Grey indices, a PCA biplot was constructed based on standardised Z-score indicators to visualise the relative positions of the underlying financial indicators, identify groups of indicators with similar behaviour, and determine the variables that contributed most to the structural transformation of Kazakhstan's financial system during 2016–2025.

The PCA biplot distributes the indicators relative to the centre of the coordinate system into four quadrants defined by the first and second principal components. The left and right sides of the graph represent negative and positive values for the first component, Dim1. The upper and lower quadrants correspond to positive and negative values for the second component, Dim2.

In Figure 1, the PCA biplot results for all four blocks of indicators are presented.



(a) Digital Transaction Activity

(b) Banking Infrastructure and Online Access

(c) Monetary and Banking Structure

(d) Financial Sector and Monetary Circulation

Figure 1. PCA biplot visualisation of structural financial indicators in Kazakhstan
Source: own evaluation

For the Digital Transaction Activity block, the first component, Dim1, explains 75.0% of the variance, and the second component, Dim2, explains 20.7%. The combined explanation exceeds 95%; thus, the PCA biplot reflects the internal structure of the transaction indicators well. The results confirm Hellwig's taxonomy and Grey Relational Analysis, which indicate that the role of digital financial transactions has increased since 2020. WEB_TRN, WEB_VOL, POS_TRN, and POS_VOL are in the positive range of Dim1, reflecting growth in online transactions and cashless POS transactions. ATM_TRN, ATM_VOL, ATM_CASH_TRN, and POS_CASH_TRN, associated with cash transactions, are in the negative range. The results show an increase in digital transactions and a decrease in cash transactions over the period under review. ATM_VOL and ATM_CASH_VOL are the outermost from the centre. Cash withdrawal transaction volumes decreased, while digital transaction indicators increased.

For the Banking Infrastructure and Online Access block, the first component, Dim1, accounts for 92.4% of the variance, while Dim2 accounts for 5.5%. Most indicators within the

block changed similarly. The results are consistent with an increase in the Taxonomic Index after 2019 and a decrease in Grey Differences in 2022–2024.

CARD_TOTAL, CARD_USED, ATM_INOUT, and ONLINE_USERS are concentrated in the positive range of Dim1. The digital banking infrastructure was evolving, and the use of banking services was increasing. ATM_OUT is located separately in the negative part of Dim1. The volume of cash withdrawal transactions declined during the period under review. ONLINE_USERS is significantly higher in Dim2. Online banking usage grew faster than the other infrastructure indicators.

For the Monetary and Banking Structure block, the first component, Dim1, accounts for 89.2% of the variance, while Dim2 accounts for 6.5%. The combined explanation exceeds 95%, so the graph reflects the main changes in monetary and banking indicators. The results are consistent with a decline in the Taxonomic Index and a gradual change in the Grey coefficients after 2020. Most indicators, including HH_CLAIM, GOV_CLAIM, DEP, TRANS_DEP, and CASH, are concentrated in the positive range of Dim1. This group saw an increase in deposit and banking components over the period under review. NFA is located separately in the upper negative sector, and NFC_CLAIM is below the second component. Net foreign assets and claims on non-financial organisations changed separately from the other indicators of the monetary structure. NFA indicators declined in the final years of the period, while NFC_CLAIM gradually increased.

In the Financial Sector and Monetary Circulation block, the first component, Dim1, accounts for 98.8% of the variance, indicating that most indicators changed in similar ways. The results are also consistent with the Grey Relational Grades, which showed the highest overall relationship for the Monetary and Banking Structure block and only slightly lower values for the remaining structural dimensions. CREDIT, F_GOV, and OUT_CASH are located at the top of the second component, while NFA and EQUITY are in the lower quadrant of the graph. Credit and government financial indicators increased more rapidly, while capital and net foreign assets changed more slowly. DEP, F_CLAIM, and F_SECTOR are located closer to the centre of the space. These indicators demonstrated gradual and more stable growth without sharp changes during the period under review.

4. Discussion

The obtained results showed an expansion of digital transactions, a reduction in the role of cash transactions, and a more rapid development of digital payments compared to changes in the monetary and financial structure, which is generally consistent with the following conclusions: Humphrey et al. (1996; 2001) on the gradual displacement of cash and paper-based transactions by electronic payments, as well as Pang et al. (2022), according to which the rapid growth of digital payments does not ensure proportional strengthening of the entire financial system and economic growth. After 2019, WEB_TRN, WEB_VOL, POS_TRN, and POS_VOL increased, while ATM_CASH_TRN and ATM_CASH_VOL decreased in the PCA biplot. The share of digital transactions and online banking services increased, and the role of cash transactions declined. At the same time, the Monetary and Banking Structure, Financial Sector and Monetary Circulation indices showed a decrease in the Taxonomic Index after 2020, despite the expansion of digital transaction activity. The growth of digital payments outpaced changes in the structure of cash, deposits, and credit. Digitalisation has changed financial transaction channels and payment behaviour, but has not ensured a synchronised strengthening of all elements of the monetary and financial system.

The study's results revealed increases in Banking Infrastructure and Online Access, driven by CARD_USED, ONLINE_USERS, and ATM_INOUT. Furthermore, an increase in

the Grey Relational Coefficients between Digital Transaction Activity and Banking Infrastructure to 0.91–1.00 after 2020 confirmed a strengthening relationship between digital transactions and remote banking services. These results are consistent with Berger's (2003) and Hughes et al. (2024) findings that the development of internet banking and remote services occurred through a reduction in reliance on the physical presence of clients and the expansion of remote banking services.

The results showed an increase in WEB_TRN, POS_TRN, ONLINE_USERS, deposit components, and claims after 2020, indicating a strengthening role for digital channels and online financial services in Kazakhstan's financial system. The high PCA explained variance for Banking Infrastructure and Online Access (92.4%) confirmed the concentration of the main structural changes in the digital segment. The Monetary and Banking Structure, the Financial Sector, and Monetary Circulation showed a decrease in the Taxonomic Index after 2020. The growth of digital transactions outpaced changes in monetary and financial components. The obtained results were generally consistent with the findings of Nabi & Suliman (2009) on the relationship between banking development, acceleration of financial transactions, and credit dynamics, as well as Wong et al. (2020), who linked digital payments with the development of online financial services, transaction speed, and reduced transaction costs.

The results showed a strengthening of the relationships among Digital Transaction Activity, Banking Infrastructure, and Online Access after 2020. Online banking services, POS transactions, and cashless payments increased simultaneously, while ATM cash withdrawals and cash transactions decreased. The obtained results are consistent with the findings of Zhang et al. (2019) on the relationship between digital infrastructure and electronic payments and the expansion of formal financial transactions and the formalisation of the economy, as well as Srivastava & Řežábek (2022) on the relationship between EFTPOS transactions, digital financial services, and economic growth. The results for Kazakhstan primarily reflected changes in the structure of financial transactions and in the transformation of the financial system, with no direct evidence of an impact on GDP growth.

The results showed that WEB_TRN, POS_TRN, ONLINE_USERS, and cashless payments increased after 2020, while ATM cash withdrawals and cash transactions declined. At the same time, the relationship between Digital Transaction Activity, Banking Infrastructure, and Online Access strengthened, and PCA confirmed the concentration of key structural changes in the digital segment of the financial system. These results are consistent with the findings of Daragmeh et al. (2021) on the growth of mobile payments and changes in user behaviour during the COVID-19 pandemic, Alchuban et al. (2022) on the spread of cashless and contactless payments, and Tut (2023), who linked the development of mobile banking to an increase in online transactions and the expansion of digital financial services.

The results showed changes in the structures of deposits, claims, reserves, and financial circulation components after 2020, accompanied by a simultaneous expansion of digital transaction activity and online financial services. At the same time, the relationship between transaction, deposit, and settlement components within the banking system has strengthened. The results are consistent with those of Carbó-Valverde (2017) and Gomber et al. (2018), who linked the development of digital financial instruments and FinTech to the redistribution of financial flows, the expansion of digital banking services, and the transformation of financial intermediation. The results are also partially consistent with Kasri et al. (2022), Cornelli et al. (2023), Liang et al. (2025), and Alfons & Pandin (2025), who considered cashless transactions and digital lending as factors in changing financial circulation and banking structure.

Conclusion

The purpose of the study was to examine how digital financial activity influenced the structural relationships between banking infrastructure and monetary indicators in Kazakhstan. Digital financial activity has increased the integration of previously relatively separate components of the financial system and made their development more interdependent. Digitalisation has changed how connections are organisedorganised within the financial system, with digital transactions serving as the connecting element among the payments sector, banking infrastructure, and monetary components. Digital transactions are now linked not only to payment transactions but also to banking infrastructure, deposits, liquidity, credit components, and money circulation.

At the beginning of the study period, digital financial activity developed primarily as an independent element of the financial system. The degree of its interconnection with banking infrastructure, monetary circulation, and the financial sector remained uneven. As digital transaction activity increased, the interconnections between individual components of the financial system intensified. Taxonomic analysis, Grey Relational Analysis, and PCA consistently showed that digital financial activity became part of the overall structure of the financial system. By the end of the study period, the differences between the structural blocks had almost disappeared. Grey Relational Grade values ranged from 0.57 to 0.58, with the strongest connections to the Monetary and Banking Structure block. This suggests that digitalisation was accompanied by a coordinated restructuring of the financial system as a whole.

From 2016 to 2018, cash was frequently used. Online transactions, online banking, and cashless services were used significantly less. During the COVID-19 pandemic of 2019–2021, the volume of cash withdrawal operations decreased. On the contrary, the number of internet transactions, online banking users, and non-cash transactions increased. After 2021, online banking, internet transactions, and cashless operations began to develop concurrently, strengthening the interconnection between digital transaction activity and banking infrastructure. At the same time, the role of deposit and credit components associated with digital financial services increased. Digital transactions, online banking, and cashless payments became central to Kazakhstan's financial system. The use of cash and some traditional banking transactions has declined.

Acknowledgement

This research received no external funding.

References

Agency of the Republic of Kazakhstan for Regulation and Development of the Financial Market. (2025). Banking sector statistics. Retrieved from: https://www.gov.kz/memleket/entities/ardfm/press/article/details/72350?lang=en (07.07.2026).

Alfons, S. K., & Pandin, M. Y. R. (2025). The Influence of Digital Banking, Company Characteristics and Capital Structure on Banking Financial Resilience with Good Corporate Governance as an Intervening Variable in Conventional Commercial Banks Listed in the LQ45 Index on the Indonesia Stock Exchange. *Indonesian Journal Economic Review (IJER)*, 5(2), 121-131. https://doi.org/10.59431/ijer.v5i2.574

Alchuban, M., Hamdan, A., & Fadhul, S. M. (2022). The usage of financial technology payments during the pandemic of Covid-19. In Future of Organizations and Work After the 4th Industrial Revolution: The Role of Artificial Intelligence, Big Data, Automation, and Robotics, 1307, 427-441. Springer. https://doi.org/10.1007/978-3-030-99000-8_24

Andrieu, M. (2001). The future of e-money: main trends and driving forces. *Foresight*, 3(5), 429-451. https://doi.org/10.1108/14636680110416779

Banna, H., & Alam, M. R. (2021). Impact of digital financial inclusion on ASEAN banking stability: implications for the post-Covid-19 era. *Studies in Economics and Finance*, 38(2), 504-523. https://doi.org/10.1108/SEF-09-2020-0388

Belke, A., & Beretta, E. (2020). From cash to central bank digital currencies and cryptocurrencies: a balancing act between modernity and monetary stability. *Journal of Economic Studies*, 47(4), 911-938. https://doi.org/10.1108/JES-07-2019-0311

Berger, A. N. (2003). The economic effects of technological progress: Evidence from the banking industry. *Journal of Money, credit and Banking*, 35(2) 141-176. https://www.jstor.org/stable/3649852

Bozhenko, V., Boyko, A., Vondráček, M., & Karácsony, P. (2024). Shadow economy and financial stability from the perspective of finance digitalization. *Journal of International Studies*, 17(2), 191-205. https://doi.org/10.14254/2071-8330.2024/17- 2/10

Carbó-Valverde, S. (2017). The impact on digitalization on banking and financial stability. *Journal of Financial Management, Markets and Institutions*, 1, 133-140. https://doi.org/10.12831/87063

Cornelli, G., Frost, J., Gambacorta, L., Rau, P. R., Wardrop, R., & Ziegler, T. (2023). Fintech and big tech credit: Drivers of the growth of digital lending. *Journal of Banking & Finance*, 148, 106742. https://doi.org/10.1016/j.jbankfin.2022.106742

Daragmeh, A., Lentner, C., & Sági, J. (2021). FinTech payments in the era of COVID-19: Factors influencing behavioral intentions of "Generation X" in Hungary to use mobile payment. *Journal of Behavioral and Experimental Finance*, 32, 100574. https://doi.org/10.1016/j.jbef.2021.100574

Dluhopolskyi, O., Pakhnenko, O., Lyeonov, S., Semenog, A., Artyukhova, N., Cholewa-Wiktor, M., & Jastrzębski, W. (2023). Digital financial inclusion: COVID-19 impacts and opportunities. *Sustainability*, 15(3), 2383. https://doi.org/10.3390/su15032383

Dos Santos, P. L., & Harvold Kvangraven, I. (2017). Better than cash, but beware the costs: electronic payments systems and financial inclusion in developing economies. *Development and change*, 48(2), 205-227. https://doi.org/10.1111/dech.12296

Frost, J., Gambacorta, L., Huang, Y., Shin, H. S., & Zbinden, P. (2019). BigTech and the changing structure of financial intermediation. *Economic policy*, 34(100), 761-799. https://doi.org/10.1093/epolic/eiaa003

Gomber, P., Kauffman, R. J., Parker, C., & Weber, B. W. (2018). On the fintech revolution: Interpreting the forces of innovation, disruption, and transformation in financial services. *Journal of management information systems*, 35(1), 220-265. https://doi.org/10.1080/07421222.2018.1440766

Gulati, T., Singla, A., & Saini, P. (2026). Digital finance in the era of digital transformation: a bibliometric analysis and systematic literature review. *Digital Transformation and Society*, 5(2), 145-169. https://doi.org/10.1108/DTS-01-2025-0018

Guo, F. H., & Liu, H. H. (2022). Grey Relational Analysis on the crucial factors of digital banking development in Taiwan. *Studies of Applied Economics*, 40(2). https://doi.org/10.25115/eea.v40i2.7840

Gurgur, T., & Kahveci, E. (2025). Digital transactions, COVID–19 and velocity of money: macroeconomic insights from an emerging market. *Applied Economics*, 1-16. https://doi.org/10.1080/00036846.2025.2540611

Hughes, L., Seddon, J. J., & Dwivedi, Y. K. (2024). Disruptive change within financial technology: A methodological analysis of digital transformation challenges. *Journal of Information Technology*, 39(4), 756-783. https://doi.org/10.1177/02683962231219512

Humphrey, D. B., Kim, M., & Vale, B. (2001). Realizing the gains from electronic payments: Costs, pricing, and payment choice. *Journal of Money, credit and Banking*, 33(2), 216-234. https://doi.org/10.2307/2673882

Humphrey, D. B., Pulley, L. B., & Vesala, J. M. (1996). Cash, paper, and electronic payments: a cross-country analysis. *Journal of money, credit and banking*, 28(4), 914-939. https://doi.org/10.2307/2077928

Jiang, S., Qiu, S., & Zhou, H. (2022). Will digital financial development affect the effectiveness of monetary policy in emerging market countries? *Economic research-Ekonomska istraživanja*, 35(1), 3437-3472. https://doi.org/10.1080/1331677X.2021.1997619

Kasri, R. A., Indrastomo, B. S., Hendranastiti, N. D., & Prasetyo, M. B. (2022). Digital payment and banking stability in emerging economy with dual banking system. *Heliyon*, 8(11). https://doi.org/10.1016/j.heliyon.2022.e11198

Khan, M. U., Nassar, S., Islam, M. F., Hossain, M. B., & Vasa, L. (2025). Is digitalization necessary for e-commerce adoption at small and medium-sized enterprises? The pandemic effects. *Entrepreneurial Business and Economics Review*, 13(4), 209-230. https://doi.org/10.15678/EBER.2025.130411

Khiaonarong, T. (2000). Electronic payment systems development in Thailand. *International Journal of Information Management*, 20(1), 59-72. https://doi.org/10.1016/S0268-4012(99)00053-5

Koh, F., Phoon, K. F., & Ha, C. D. (2018). Digital financial inclusion in South east Asia. In Handbook of Blockchain, Digital Finance, and Inclusion, 2, 387-403. *Academic Press*. https://doi.org/10.1016/B978-0-12-812282-2.00015-2

Kráľ, Š., Kráľová, L., Gavura, Š., & Bačík, R. (2025). Generational differences in the perception of e-commerce aspects: An empirical study of Slovak consumers. *Economics and Sociology, 18*(4), 116-130. doi:10.14254/2071-789X.2025/18-4/6

Kurucz, A., Vinkóczi, T., Tamás, B., & Idziak, E. (2025). Unveiling the Future of FinTech: Exploring the Behavioral Intentions Behind FinTech Adoption. *Journal of Risk and Financial Management,* 18(10), 546. https://doi.org/10.3390/jrfm18100546

Liang, Y., Wei, R., & Duan, D. (2025). Digital financial development and commercial bank stability. *International Review of Economics & Finance*, 97, 103749. https://doi.org/10.1016/j.iref.2024.103749

Ligon, E., Malick, B., Sheth, K., & Trachtman, C. (2019). What explains low adoption of digital payment technologies? Evidence from small-scale merchants in Jaipur, India. *PloS one,* 14(7), e0219450. https://doi.org/10.1371/journal.pone.0219450

Liu, W. C., & Hsu, C. M. (2006). The role of financial development in economic growth: The experiences of Taiwan, Korea, and Japan. *Journal of Asian Economics*, 17(4), 667-690. https://doi.org/10.1016/j.asieco.2006.06.007

Makarenko, I., Steiner, B., Yuhai, K., & Makarovych, V. (2025). The role of sector-specific SDG policies, governance quality and finance for SDG progress. *Economics and Sociology, 18*(4), 11-39. doi:10.14254/2071-789X.2025/18-4/1

Nabi, M. S., & Suliman, M. O. (2009). Institutions, banking development, and economic growth. *The Developing Economies*, 47(4), 436-457. https://doi.org/10.1111/j.1746-1049.2009.00093.x

National Bank of Kazakhstan. (2025). Banks' performance. Retrieved from: https://nationalbank.kz/en/news/banks-performance/rubrics/2381 (07.07.2026).

Pakhnenko, O., Rubanov, P., Hacar, D., Yatsenko, V., & Vida, I. (2021). Digitalization of financial services in European countries: Evaluation and comparative analysis. *Journal of International Studies*, 14(2), 267-282. https://doi.org/10.14254/2071-8330.2021/14-2/17

Pang, Y. X., Ng, S. H., & Lau, W. T. (2022). Digital cashless payments and economic growth: evidence from CPMI countries. *Capital Markets Review*, 30(2), 63-89. https://mfa-cmr.com/cmr/article/view/93

Paduszyńska, M., & Lesiak, M. (2022). Analysis of banking sector stability using the taxonomic measure of development. *Ekonomia i Prawo. Economics and Law*, 21(4), 741-761. https://doi.org/10.12775/EiP.2022.040

Puschmann, T. (2017). Fintech. *Business & Information Systems Engineering*, 59(1), 69-76. https://doi.org/10.1007/s12599-017-0464-6

Putrevu, J., & Mertzanis, C. (2024). The adoption of digital payments in emerging economies: challenges and policy responses. *Digital Policy, Regulation and Governance*, 26(5), 476-500 https://doi.org/10.1108/DPRG-06-2023-0077

Quoc, H. N., Van, H. N., & Le Quoc, D. (2025). Financial inclusion in the digital era and its impact on sustainable development across ASEAN countries through combined nonparametric methods. *Discover Sustainability*, 6(1), 1378. https://doi.org/10.1007/s43621-025-02439-4

Roshchyk, I., Oliinyk, O., Mishchuk, H., & Bilan, Y. (2022). IT Products, E-Commerce, and Growth: Analysis of Links in Emerging Market. *Transformations in Business & Economics, 21*(1), 209-227.

Shahen, A. M., & Sharaf, M. F. (2026). Digital payments as a conceptual pathway linking COVID-19 and financial inclusion: A PRISMA-based systematic review and bibliometric analysis. *Journal of Theoretical and Applied Electronic Commerce Research*, 21(4), 108. https://doi.org/10.3390/jtaer21040108

Shaikh, A. A., Glavee-Geo, R., & Karjaluoto, H. (2017). Exploring the nexus between financial sector reforms and the emergence of digital banking culture–Evidences from a developing country. *Research in International Business and Finance*, 42, 1030-1039. https://doi.org/10.1016/j.ribaf.2017.07.039

Srivastava, A., & Řežábek, P. (2022). Impact of Digital Payments on the Economic growth of a country-A case of the Czech Republic. *International Journal of Economic Sciences*, 11(1), 85-104. https://doi.org/10.52950/ES.2022.11.1.006

Tut, D. (2023). FinTech and the COVID-19 pandemic: Evidence from electronic payment systems. *Emerging Markets Review*, 54, 100999. https://doi.org/10.1016/j.ememar.2023.100999

Yarovenko, H., Ohol, D., Ashirbekova, L., & Popp, J. (2025). Digital transformation and economic development in Europe: Classical and machineoriented approaches. *Journal of International Studies*, 18(4), 256-284. https://doi.org/10.14254/2071-8330.2025/18-4/13

Yoganandham, G. (2024). Transformative impact: The role of modern and innovative banking technologies in driving global economic growth. *Tuijin Jishu/Journal of Propulsion Technology*, 45(1), 2024.

Zhang, Y., Zhang, G., Liu, L., De Renzis, T., & Schmiedel, H. (2019). Retail payments and the real economy. *Journal of Financial Stability*, 44, 100690. https://doi.org/10.1016/j.jfs.2019.100690

Wong, T. L., Lau, W. Y., & Yip, T. M. (2020). Cashless payments and economic growth: Evidence from selected OECD countries. *Journal of Central Banking Theory and Practice*, 9(s1), 189-213. https://doi.org/10.2478/jcbtp-2020-0028